NOMINATION OF THE REFRIGERATION PLANT AND COLD ROOMS AT URRBRAE HOUSE FOR A COMMEMORATIVE PLAQUE

5 February 1996

By the South Australian Division
The Institution of Engineers Australia

NOMINATION OF THE URRBRAE HOUSE REFRIGERATION PLANT AND COLD ROOMS FOR A COMMEMORATIVE PLAQUE

CONTENTS

Introduction

This nomination for the award of an Historic Engineering Marker to the refrigeration plant and cold rooms at Urrbrae House in South Australia is made by the Committee of the Engineering Heritage Branch of the S.A. Division of the Institution of Engineers, Australia. In this task it has been assisted by the Restoration of Ancient Refrigeration Equipment (RARE) Committee set up by the Waite Agricultural Research Institute of the University of Adelaide. The membership of this committee is:

Mr Ray White (Director, White Refrigeration Pty. Ltd.)

Ms Yvonne Routledge (Curator, Urrbrae House Historical Precinct)

Mr Bernard Arnold (Finance Officer, Faculty of Agricultural & Natural Resource Sciences)

Dr John Pickles (Hon. Sec., Engineering Heritage Branch Committee, SA Division, IEAust).

If the nomination is approved it is hoped that it will be possible to make the unveiling ceremony part of the annual conference of the Australian Institute of Refrigeration, Airconditioning and Heating on April 17th 1996.

LOCATION

The refrigeration plant and cold rooms are located in the basement of Urrbrae House, the centrepiece of the Urrbrae Historical Precinct in the south-eastern corner of the University of Adelaide's Waite campus bounded by Fullarton Road, Cross Road, Waite Road and Claremont Avenue (S.A. Lands Department Map 6628-111: Ref. 839 276).

Access to Urrbrae House is via Gate 3 on Waite Road. The location is shown on the map below.

Commemorative Plaque Nomination Form

Date 5 February 1996

From Heritage Branch

Committee IEAust.

S.A.Division

Nominating Body

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
Engineering House
11 National Circuit
BARTON ACT 2600

The following work is nominated for a:-

- ~~National Engineering Landmark~~
- Historic Engineering Marker

*(delete as appropriate)

Name of work: Urrbrae House Refrigeration Plant & Cold Rooms.

Location, including address and map grid reference if a fixed work: Urrbrae House, University of Adelaide, Waite Campus, Glen Osmond, SA 5064. (Map Ref. 839 276)

Owner: The University of Adelaide

The owner has been advised of the nomination of the work and has indictated (attach a copy of letter if available): Full support (Letter attached).

Access to site: Contact Ms. Y. Routledge (Curator).

Future care and maintenance of the work: The responsibility of the University of Adelaide.

Name of sponsor: -

For a NEL, is an information plaque required? -

Chairperson of Nominating Committee

Chairperson of Division Heritage Committee/Panel

ADDITIONAL SUPPORTING INFORMATION

Name of work: Urrbrae House Refrigeration Plant & Cold Rooms.

Year of construction or manufacture: 1895

Period of operation: Not known

Physical condition: Excellent; being restored to running order.

Engineering Heritage Significance:-

Technological/scientific value: Illustrates transition from steam to electric power. Design is first successful commercial use of ammonia.

Historical value: First domestic refrigeration system in Australia.

Social value: Early application of refrigeration for domestic purposes.

Landscape or townscape value: -

Rarity: Earliest operating domestic refrigeration system in Australia.

Representativeness: Adaptation of industrial practice.

Contribution to the nation or region: ...

Contribution of engineering: ...

Persons associated with the work: Peter Waite; Professor Carl Linde; Wildridge & Sinclair Ltd.

Integrity: System unchanged since installation.

Authenticity: Makers nameplate; original drawings; Urrbrae House history.

Comparable works(a) in Australia: None known

(b) overseas: Not known

Statement of significance, its location in the supporting documentation: See page 7

Citation (70 words is optimum): See page 8

Attachments to submission (if any): See attached list page 9

Proposed location of plaque (if not at site): On outside of building housing the plant.

Letter of Support

THE UNIVERSITY OF ADELAIDE

Susan Graebner
Campus Registrar, Waite & Roseworthy

17 October 1995

Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
Engineering House
11 National Circuit
BARTON, ACT 2600

Dear Members,

The University of Adelaide is delighted to support the nomination by the Restoration of Ancient Refrigeration Equipment Committee of the Urrbrae House coldrooms and refrigeration plant to your Institution for an Historic Engineering Marker plaque.

Urrbrae House forms part of the Historic Precinct on the University of Adelaide's Waite Campus and the restoration and preservation of the historic items of the Precinct is consistent with the University's Master Plan.

Yours faithfully,

Susan Graebner
for D R Beecher
Acting Registrar

Waite Campus, PMB 1, Glen Osmond, SA 5064
Tel: (08) 303 7402 Fax: (08) 303 7106
sgraebner@registry.adelaide.edu.au

Statement of Significance

The refrigeration system and associated cold rooms in the basement of Urrbrae House on Waite Campus of the University of Adelaide is the earliest known application in Australia of the then current commercial refrigeration practice for domestic use.

The design and installation of this innovative system was contracted by pastoralist Peter Waite to the firm of Wildridge & Sinclair of Sydney. It was installed in 1895 and, according to an early catalogue, it was Wildridge & Sinclair's first domestic installation. The firm has only recently (1989) gone out of business.

The ammonia compressor was manufactured by the Linde British Refrigeration Company under the design supervision of the German academic and industrialist Professor Carl Linde, who had introduced the ammonia machine in 1876. The design of this compressor differs little from the earliest machines, and the design was the first to be produced in large numbers.

The design of the compressor reflects established steam engine technology of the time. The piston is double acting, driven by a crankshaft running at 120 rpm, and the operating pressures of 20 psig and 170 psig were similar to those used in contemporary steam

The compressor provides an interesting instance of the era of transition from steam to electric power. The frame and crankshaft have provision for the mounting of a steam cylinder to power the machine, but in this installation an electric motor was used.

The plant appears to be unchanged since its original installation; the original colour-washed layout drawing survives. All the equipment and components are original, apart the 32 volt DC electric drive motor which is missing. This is being replaced with a c1905 AC motor. The components are generally in excellent condition and the plant is being restored to operation.

CITATION

Urrbrae House Refrigerator and Cold Rooms

This refrigeration plant and cold rooms is the earliest example of domestic refrigeration in Australia. It was installed in 1895 by Wildridge & Sinclair of Sydney (1890-1989) for the pastoralist Peter Waite (1834-1922). It utilises a vertical double-acting ammonia compressor designed in Germany in 1876 by Prof. Carl Linde (1842-1934) and built by Linde British Refrigeration Company. This was the first commercially viable ammonia compressor design and was produced in large numbers.

Dedicated by

The Institution of Engineers, Australia and The University of Adelaide

Attachments to Submission

1. Technical Description of the Urrbrae House Refrigerator and Cold Rooms

Urrbrae House is the former family home of pastoral pioneer Peter Waite. Peter Waite was born near Kircaldy, Fifeshire, Scotland in 1834. As a lad he was apprenticed to an ironmonger in Edinburgh. In 1859 he arrived in Melbourne and shortly after joined his brother James on his property near Terowie in South Australia. In the ensuing years his fortunes prospered so that, in partnership with Sir Thomas Elder, he eventually owned extensive interests in a number of pastoral properties. Peter Waite was well known for his innovative approach to pastoralism: he demonstrated the advantages of fenced properties, importing 265 tons of fencing wire from England in 1870, and, realising their worth in our arid environment, bred camels and donkeys extensively. In 1874 Peter Waite's business interests brought him to Adelaide and he purchased "Urrbrae". The original Urrbrae property had been established in 1839 and a single storey house was constructed in 1844. Fifteen years after his purchase of the property Peter Waite decided to rebuild the old home and by the end of 1889 a two storey mansion of thirty-five rooms had been erected. The new home reflected Peter Waite's innovative outlook, featuring such novelties as a tiled roof and a 32 volt DC lighting system supplied from a large bank of batteries. The surviving battery house contains a plinth for a generator which seems to have been driven initially by a portable steam engine located outside the building, with the flat belt passing through a steel-framed slit in the wall. Later the steam engine was replaced with an oil engine.

The refrigeration plant was installed in 1895 by Wildridge & Sinclair of Pitt Street, Sydney, using a compressor built by the Linde British Refrigeration Company of London. Dr Carl Linde had patented a new compression process using liquid anhydrous ammonia in 1873. In 1876 Linde produced the first commercial machine operating on this system. Refrigeration in various forms had been in use for a number of years: John Gorrie, an American, is credited with having invented the first practical refrigerating machine in 1849; the first meat freezing works in the world was set up at Darling Harbour, Sydney, in 1861; and in 1874 the New South Wales Fresh Food & Ice Company was set up, using ammonia compression machinery. The unit at Urrbrae House is the first adaptation of commercial refrigeration technology for domestic use in Australia.

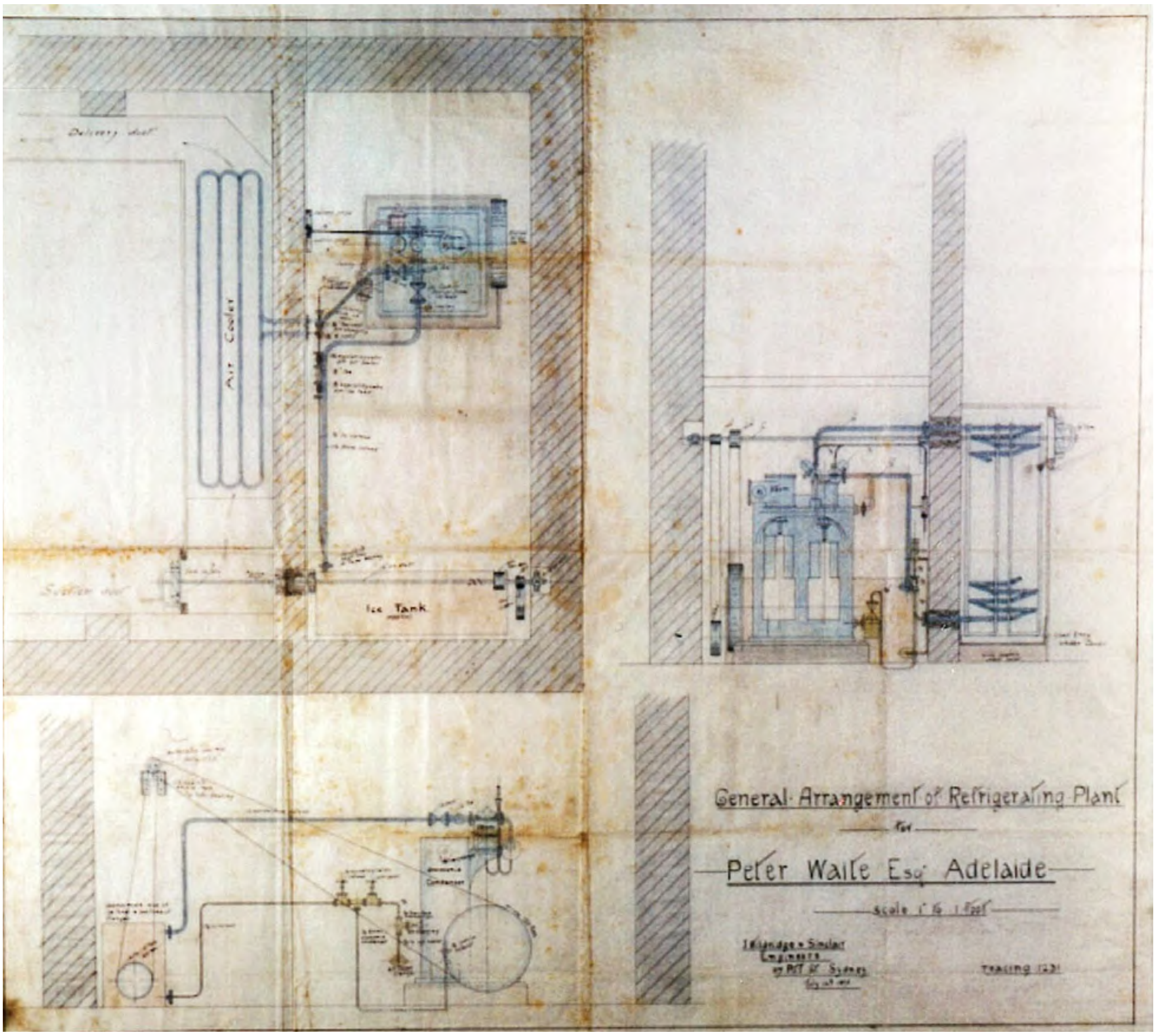
The Urrbrae House compressor is a vertical single cylinder two-stage unit with spring-closed poppet valves. The piston rod is driven by a crankshaft and crosshead arrangement running at 120 rpm. The original hand-tinted layout drawing, which has survived in the Waite archives, shows a steam cylinder adjacent to the compressor cylinder, both coupled to a common crankshaft. However, although there is a second crank on the crankshaft and mountings for a steam cylinder on the cast iron bed, none was supplied. Peter Waite opted instead for an electric motor supplied from the house's 32 volt two-wire DC system driving the crankshaft by means of a flat belt. The motor has not survived, although its plinth remains. However, the use of a customer list in a Wildridge & Sinclair catalogue of c1910, enabled Ray White of the RARE Committee to locate a General Electric induction motor that used to drive a similar Linde compressor in a butcher's shop in Broken Hill. The 8 hp motor was designed for 40 cycles at 550 volts, and a no load speed of 800 rpm, but was rewound some years ago for present supply conditions. It was purchased and used to drive the Urrbrae compressor

The ammonia condenser is integral with the vertical compressor bed-plate and consists of a number of wrought iron coils carrying the refrigerant and contained in a cast iron chamber through which cooling water is circulated. The evaporator consists of a single serpentine wrought iron tube located in an air plenum. Air is cooled by being drawn over the evaporator tube by a fan of unusual (and probably inadequate) design, driven from the motor shaft via a rope belt and layshaft.

The fan discharges into a wooden duct which conveys the cooled air to three wood-lined and charcoal insulated cold-rooms (see Architect's plan, page 12). The air flow to the three rooms can be controlled by opening and closing a number of hinged flaps and sliding shutters, both into the rooms end within the ductwork itself, the latter being operated by pull-wires terminating in brass acorns. The first room, closest to the evaporator plenum, was used for meat storage. It was possible to divert the full flow from the fan into this room to provide rapid chilling of meat. The second room has a false ceiling of corrugated iron, the cold air passing through the ceiling space rather than directly through the room; this was probably to protect fruit and vegetables from burning due to direct contact with moving chilled air. The third room was a general purpose cold store, the chilled air passing directly through the room. The discharge air from the rooms is ducted back to the evaporator plenum. A small hinged flap in the wall of the second room, leading to a vertical duct, seems to that it may have been possible to divert cool air to the upper rooms of the house in summer. The head, jambs and threshold of the 200 mm thick cold-room doors are angled and lined with blankets to ensure a good seal. Control of cold-room temperature is by manual adjustment of a regulating valve upstream of the evaporator coil, room temperature being monitored by a thermometer inserted in a brass pocket in each of the cold-room doors.

2. Original Layout Drawing (1895)

The original colour washed layout drawing prepared by Wildridge & Sinclair was discovered in the Waite House archives. It differs in some respects from the final installation.



3. Extracts from Wildridge & Sinclair Catalogue

Extracts from Wildridge & Sinclair's *Catalogue of "LINDE" Refrigerating Machines* (c.1910), pp. 1, 2 & 57.

Wildridge & Sinclair, Engineers and Machinery Merchants of 82 Pitt Street, Sydney, were the Australia and New Zealand agents for Linde refrigeration compressors. In about 1910 their South Australian agents were Gibbs, Bright & Co, 27 Grenfell Street, Adelaide; it is not known if this was the case in 1895 when the plant was installed at Urrbare House.

Page 57 of the catalogue lists Wildridge & Sinclair's Linde installations in Australia and New Zealand, presumably in chronological order. Towards the bottom of this list is the entry:

"Waite ... Adelaide ... Private dwelling" appears.

The list contains no other entry for a private dwelling.

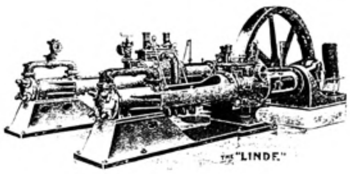
J. WILDRIDGE & SINCLAIR
LIMITED

Engineers and Machinery Merchants,

Vickery's Chambers, 82 Pitt Street, Sydney.

ALSO

VICTORIA 590 Elizabeth Street, Melbourne.
WESTERN AUSTRALIA Queen's Buildings, 293 Murray Street, Perth.
NEW ZEALAND Brunswick Buildings, 174 Queen St., Auckland.
QUEENSLAND J. WILDRIDGE & SINCLAIR (Brisbane) Ltd. 228-230 Elizabeth Street, Brisbane.
SOUTH AUSTRALIA Agents: Gibbs, Bright & Co., 27 Grenfell Street, Adelaide.



Catalogue of "LINDE" Refrigerating Machines

LARGE STOCKS, MACHINES AND FITTINGS ALWAYS CARRIED.

SEPARATE FITTINGS CATALOGUE SENT ON APPLICATION.

1

PREFACE.

IN presenting this Catalogue to the users of **Refrigerating and Ice-making Machinery**, we do so with the view of describing the construction and advantages of the "**Linde**" machinery as supplied by us.

Purchasers of Refrigerating Machinery should bear in mind that the machine that may be lowest in first cost is not necessarily the cheapest; as, in addition to first cost, there is the cost of running expenses and repairs from year to year to be taken into consideration; therefore the value of a plant has to be judged by its construction, durability, and the results obtained.

The total number of "**Linde**" machines in use all over the world is now just on 9000. This fact alone, when compared with the output of **other types of machinery**, proves its value when judged by its **construction, durability** and **results of working.**

The machines illustrated throughout this Catalogue range in capacity from 20 cwt. to 500 tons refrigeration per twenty-four hours. **No plant is too small** for our attention, and we want intending purchasers to remember that **our guarantee of excellence** is given with **every order** received by us, irrespective of the size of plant.

The owners of "**Linde**" **machines** are freely mentioned throughout the following pages, and we feel confident that such owners will be, on application, pleased to give intending purchasers the results of their experience with the

LINDE MACHINE

Yours truly,

J. WILDRIDGE & SINCLAIR Ltd.

2

SUPPLIED TO	PLACE	NATURE OF WORK
llington Meat Export Co.	Wellington	Meat freezing.
son Brothers, Ltd.	Waipukurau	" "
son Brothers, Ltd.	Hornby	" "
nganui Meat Freezing Co.	Wanganui	" " and ice
son Brothers, Ltd.	Tomoana	" " and chilling.
" "	Gisborne	" "
" "	Bluff	Freezing rabbits.
" "	Gisborne	Meat freezing and chilling
" "	Woodville	" "
" "	Woodville	Bacon curing.
" "	Tomoana	Meat freezing.
" "	Tomoana	" "
istchurch Meat Co., Ltd.	Timaru	" "
llington Meat Export Co. Ltd.	Wellington	" "
tional Mortgage & Agency Co.	Longburn	" "
stern Packing and Canning Co.	Patea	" "
t & Co., Ltd.	Bluff	" "
T. Murray & Co., Invercargill	Invercargill	Condensed milk factory.
ttleton Harbour Board	Lyttleton	Cold storage.
ranaki Freezing Works Company	New Plymouth	" " and ice.
rdell Brothers & Co.	Christchurch	" " and bacon curing
ranaki Freezing Works Company	New Plymouth	" "
. Niven & Co.	Napier	" " and ice.
nes Ruddin	Invercargill	Chilling rabbits.
Dimock & Co.	Wellington	Bacon curing and ice.
red Drake	New Plymouth	Bacon curing.
atford Bacon Curing Co., Ltd.	Stratford	" "
J. Sullivan	Dunedin	Freezing fish.
ribilli Stores	North Sydney	Meat freezing and storage.
nicipal Markets	Sydney	Fish and meat stores.
nicipal Markets	Melbourne	Fish and meat stores.
nicipal Markets	"	General Produce, fish and
Connelly & Co.	"	Butcher's room [meat stores
rth Ice Works	Perth	Meat stores & ice making.
operative Butchering Co.	Armidale	Meat chilling & ice making.
at Chilling Works	Young	" " " "
aly & Malcolm	Harrisville	Cheese cooling store.
at Works	Brisbane	Meat chilling, meat freezing [and storage.
at Works	Townsville	Meat chilling, meat freezing [and storage.
ks Brothers	Shellharbour	Bacon curing.
wes & Co.	Brisbane	Bacon curing.
McKenzie	Wollongong	Meat chilling.
at Works	Dubbo	Meat chilling & ice making.
inra Dairy Co.	Allora	Dairy refrigerating and ice making.
oth's Brewery	Sydney	Liquid cooling.
H. Couldrey	Cedar Grove	Cheese cooling store.
at Works	Bowen	Meat freezing and storing.
Waite	Adelaide	Private dwelling.
Waite	Adelaide	Private dwelling.
stern and Wimmera Districts of Victoria Freezing Co., Ltd.	Geelong	Meat freezing.
elbourne Brewery & Distill'y Co.	Melbourne	Liquid cooling.
ke's Creek Works	Queensland	Meat freezing.
arleville Meat Co.	Charleville	Meat chilling & ice making
odel Dairy Co.	Brisbane	Dairy refrigeration
cArthur & Co.	Sydney	Chilling produce
wood Creamery Co., Queensland	Lowood	Dairy refrigeration.
McMillan	Coolgardie	Meat chilling & ice making
arshall's Brewery	Paddington	Water cooling.
Lamb	Thursday Island	Ice making and chilling.
J. Freame	Melbourne	Meat chilling.

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4. Reference from *The Engineer* (1899)

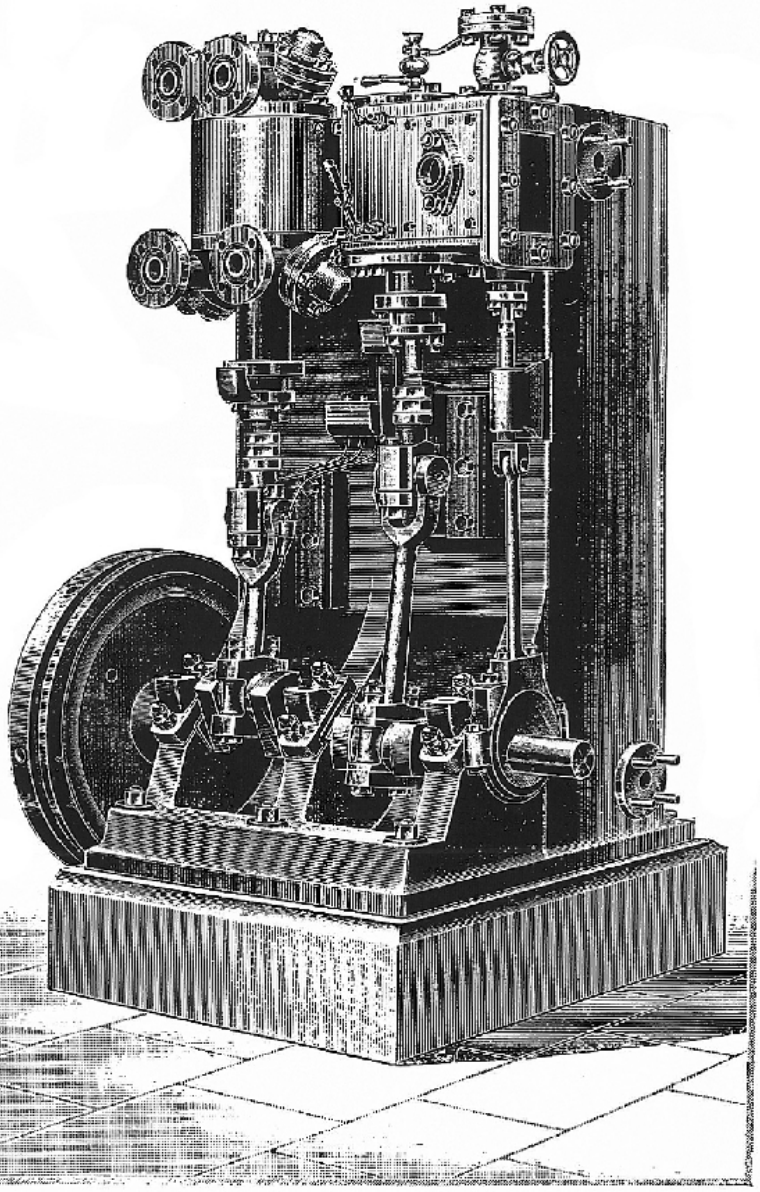
This extract from *The Engineer,* 20 January 1899 [pp 65,66] shows a machine identical to that installed at Urrbrae House except that the Waite machine has no steam cylinder (on the right in the figure).

> The description states that the illustration "... shows a self-contained Linde marine machine, such as is used for preserving provisions and making ice on board passenger ships. In those cases it is usual to have two or more insulated compartments in which the desired temperatures are maintained by direct expansion or by brine pipes, the last named being the most usual arrangement. The machine cools brine to a temperature of about zero Fahrenheit, and this cool brine is then circulated partly through brine pipes placed in suitable positions in the rooms, and partly through a tank containing the necessary moulds for ice making. The machine consists of a hollow frame containing the condenser coils. The compressor, which in this case is of the vertical type, is mounted on the front of the frame and driven by a steam engine fixed alongside. The exhaust steam from the engine is generally led into the condenser of the main engine, and in port, when the main engines are not working, either into the auxiliary condenser or the feed tank."

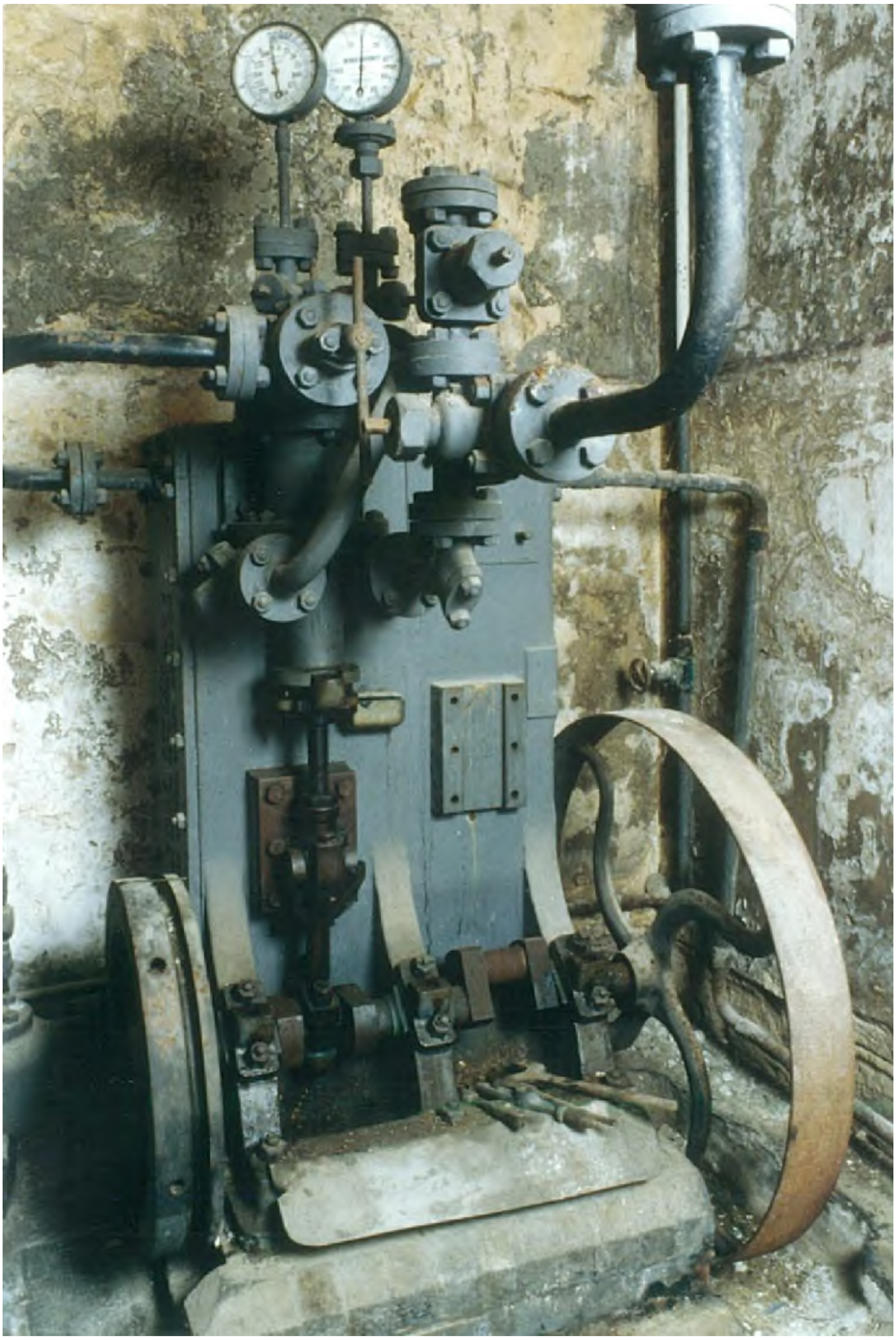
MARINE REFRIGERATOR FOR PASSENGER VESSELS

MESSRS. THE LINDE BRITISH REFRIGERATION CO., LONDON, ENGINEERS

(*For description see page 65*)

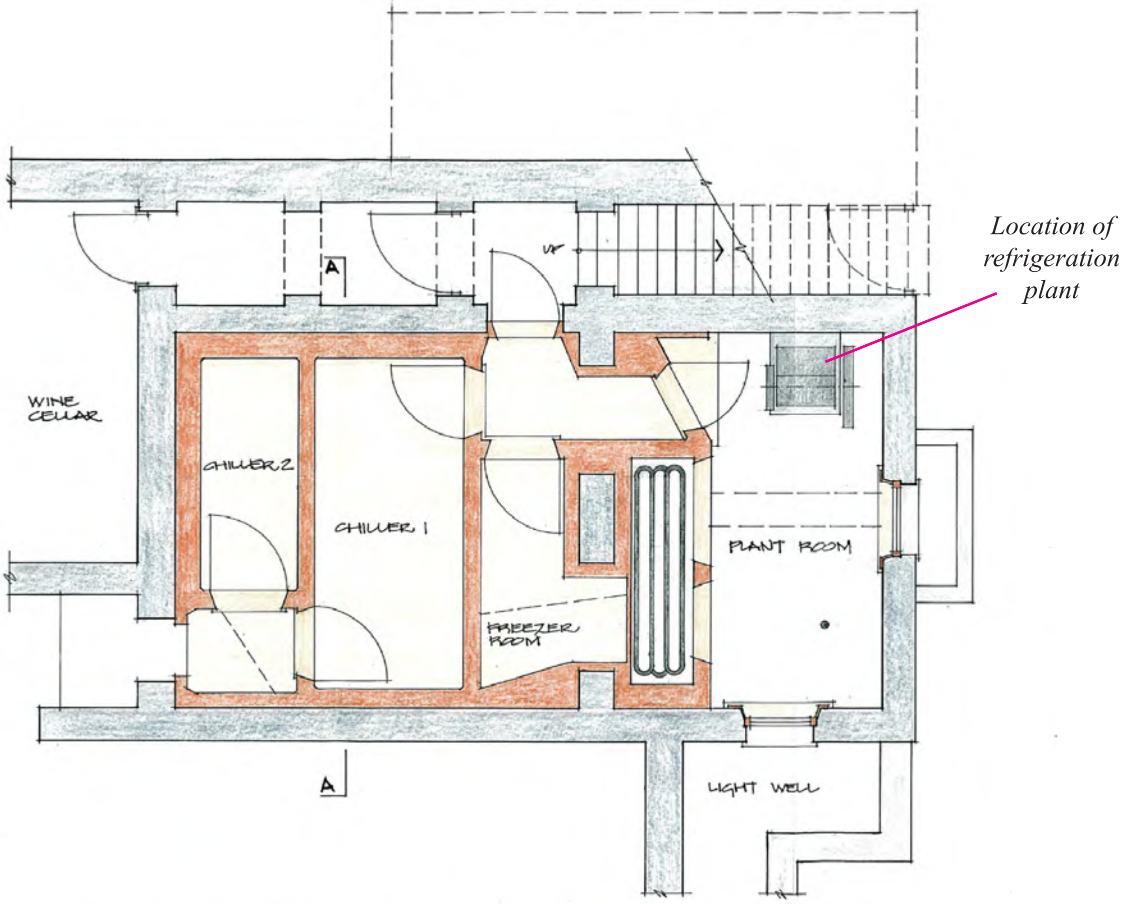


Comparing the photograph of the Waite compressor with the drawing from *The Engineer*, the mounting pads for the steam cylinder and the crosshead bearing are clearly seen. The right hand end of the crankshaft is fitted with a pulley wheel which was driven by a flat belt from the electric motor.

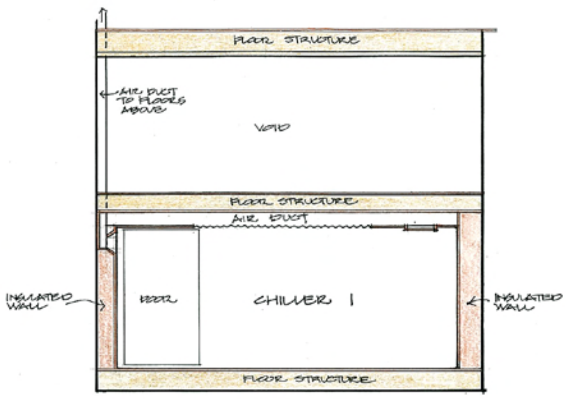


5. Architect's Drawing of Room Layout

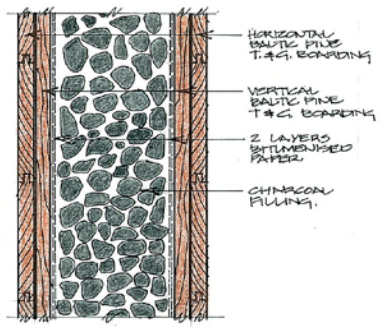
The measured architect's drawings show the plant room (with the compressor location), the evaporator coil plenum, the adjacent freezer room, and the two cold rooms (chiller 1 and chiller 2). The construction of the insulated walls is also shown.



PLAN OF BASEMENT REFRIGERATING ROOMS



SECTION A-A



SECTION THROUGH COOLROOM WALL

6. Linde: Father of the Ammonia Compressor

Carter, P. (1984), *Australian Refrigeration, Air Conditioning and Heating*, December, pp. 34, 35.

Carter summarises Linde's career and shows that today's ammonia compressors are direct descendants of his designs. The design of the compressor cylinder shown in Figure 3, introduced in 1877, is the same as that in the Waite machine.

Linde: Father of the ammonia compressor

By Peter Carter

Fifty years have now passed since the death of Carl von Linde on November 16, 1934. He was then over 90 years old and most of his work had been done long before. However, it was of such importance in the history of refrigeration that I think it justifies a few notes in our Journal.

Carl von Linde

Linde was born on June 11, 1842 at Berndorf in Upper Franconia, now in West Germany. He was the third of nine children and his father was a minister. After completing his school education, he attended the Zuerich Polytechnic, where Rudolf Clausius was one of his teachers. Clausius introduced the notion of entropy and has been called "the first to establish thermodynamics as a science". It was probably his example that gave the young Linde an abiding enthusiasm for thermodynamics.

During the next few years Linde obtained industrial experience which included employment in the Krauss locomotive works in Munich*. His purpose however was to pursue an academic career and in 1868, when the Munich Polytechnic School was founded, he became its Extraordinary Professor of Mechanical Engineering. Later he became a full Professor and established a famous engineering laboratory.

In 1870 the young Professor contributed to a Bavarian technical magazine an article entitled "On heat extraction at low temperature by mechanical means", in which he calculated the efficiency of cold air machines, vapour compression machines and absorption machines. He showed that none of the machines that had been built up to that time would deliver more than one fifth of the cooling capacity that was theoretically obtainable, and went on to explain how better results could be achieved. In 1873 he lectured on the same subject before the international brewery congress in Vienna. His arguments impressed the brewers and he was given promises of active support.

Lager beer was and is produced in Germany and Austria by the bottom fermentation process, in which yeast sinks to the bottom of the fermenting tank. The temperatures required are 6 to 8 degrees C. for fermentation and 0 to 4 degrees C. for storage of the beer. These temperatures were attained by a lavish use of natural ice and so there was an obvious market for refrigeration plant.

During the years 1873 and 1874 Linde and his pupil F. Schipper worked on the design of a new compressor. For refrigerant he chose methyl ether $(CH_3)_2O$, which boils at minus 23.6 degrees C. and so avoids the sub-atmospheric pressures which had bothered Harrison using ethyl ether. However, both ethers are very explosive when mixed with air and so Linde was driven to take extraordinary measures to avoid leakage (Fig. 1). The main piston operated on a secondary fluid, probably oil, which was separated from the refrigerant by secondary pistons, or "bells", the skirts of which were sealed with mercury. This was a very complicated and slow-running machine suitable only for a laboratory.

By 1874, Linde had realised the advantages of ammonia and he began the design of a second compressor using ammonia as refrigerant. It was a twin-cylinder vertical machine and the space below the pistons was filled with lubricant in communication with a common receiver (Fig. 2). It will be seen that the stuffing boxes are in contact with lubricant but not with ammonia vapour. The first of these compressors emerged from a factory in Augsburg in 1876. They were considered to be successful and one of them is known to have worked in a brewery in Trieste from 1877 to 1908.

Linde produced a third design in 1877 (Fig. 3). It was a horizontal double-acting machine which remained standard for many years to come. Note the stuffing box, which contained a lantern between two sets of packings and was lubricated with glycerine or mineral oil in communication with the suction side of the compressor. It was manufactured in Augsburg and also under licence by Sulzer in Switzerland, Carel in Belgium, Morton in England and the Fred. W. Wolf Co. in Chicago, USA.

In 1879, Linde gave up teaching to devote himself entirely to the refrigeration industry. He founded his own manufacturing company in Wiesbaden. In 1881 there were already 750 Linde machines in 445 breweries. In 1883 Linde provided refrigeration plant for the Wiesbaden abattoir, in which the air was cooled by slowly rotating discs partially immersed in refrigerated brine. This was very successful and 90 such installations had been made by 1891.

In March 1894, Linde visited London and lectured at a meeting of the Society of Arts. This society was already ancient, having been founded in 1754 to foster industry and the arts. Twenty years before it had shown interest in Harrison's unsuccessful meat shipment. It kept a detailed record of its activities and I have the tran-

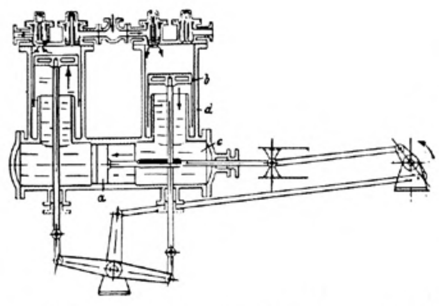


Fig. 1: First Linde compressor (*a* = piston, *b* bell, *c* fluid, *d* mercury).

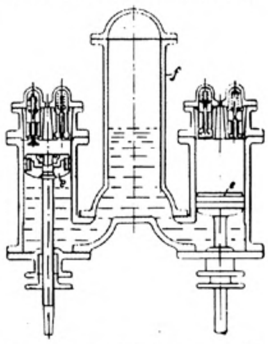


Fig. 2: Second Linde compressor (*e* piston, *f* air vessel or receiver).

**His first published work was a paper on Railway Braking Systems (1868)*

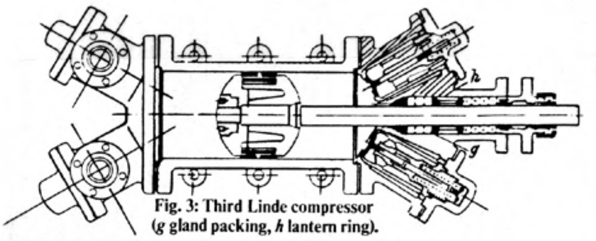


Fig. 3: Third Linde compressor (*g* gland packing, *h* lantern ring).

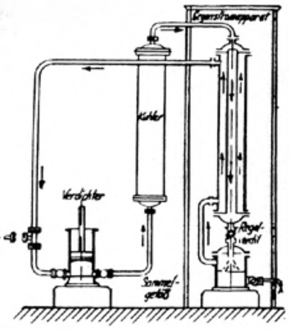


Fig. 4: First Linde liquid air plant.

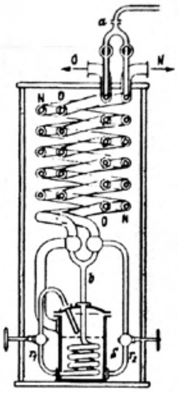


Fig. 5: Linde oxygen plant.

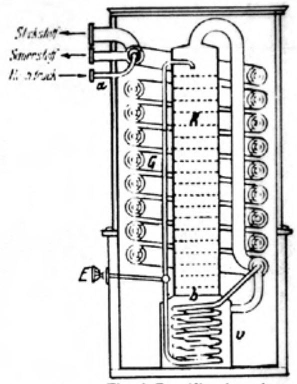


Fig. 6: Rectification plant by Friedrich Linde.

script of Linde's lecture, which may well have been an updated version of his original paper of 1870. He reviewed the thermodynamics of refrigeration, compared the performance of existing systems (the Bell-Coleman cold air system, ammonia vapour compression, carbon dioxide vapour compression and ammonia absorption) and concluded that ammonia vapour compression was the most efficient system. In the ensuing discussion Louis Sterne, a Glasgow manufacturer, remarked that the paper was most interesting, but, being purely theoretical, he was not able to say anything about it. An Army colonel reminisced about his experiences in India, where ammonia absorption machines were found to be very valuable for domestic purposes, and had almost destroyed the industry of producing ice naturally. In the natural process, shallow vessels of water were exposed at night in cold weather to produce thin sheets of ice which were stored, presumably in some sort of insulated store, for use in hot weather. Other speakers were concerned to defend the cold air and carbon dioxide systems, stressing the safety aspect, since ammonia is poisonous (less than one per cent by volume in air can kill in half an hour) and is also explosive (when mixed with air in proportions between 16 and 25 per cent by volume).

Cold air machines were already past the peak of their popularity. In a typical cold air plant air returning from the cold store would pass through a heat exchanger called the "dryer", be compressed to about 350 kPa gauge in a compressor, be cooled in a water-cooled heat exchanger called the "cooler", pass through the other side of the dryer wherein moisture would be condensed and removed, be expanded in an expander wherein it would be cooled by doing external work and finally re-enter the cold store at a very low temperature. The compressor and expander were separate cylinders on the one machine. Cold air machines were large and expensive and the C.O.P. was only about 0.75. Carbon dioxide compressors were being made by J. & E. Hall of Dartford and were popular for marine use up to World War II. Disadvantages of carbon dioxide are high operating pressures and also reduced cycle efficiency above the critical temperature (temperature above which it will not liquefy, 31 degrees C.).

Linde replied systematically to all questions, a vote of thanks was proposed and carried, and we may imagine that Linde took a hansom cab to his hotel while the audience made their way through the fog to join smutty steam trains back to their gas-lit suburban homes.

At this time Linde was developing a new interest, the production of liquid air on an industrial scale, and the separation from it of pure oxygen and nitrogen. He had been following the experiments of Professor Dewar, a rather irascible Scottish chemist who deserves our gratitude for inventing the vacuum flask. Dewar had produced liquid air by a cascade refrigeration plant, using methyl chloride or carbon dioxide in the first stage and ethylene in the second stage. Linde first thought of using the Bell-Coleman cold air cycle to produce liquid air, but the lubrication of the expansion cylinder proved to be too difficult and he decided to use a simpler method. When an ideal gas (which is one that obeys the Ideal Gas Law) expands through a throttling valve, doing no external work, it does not change its temperature. Most real gases, including air, are under normal conditions a bit more compressible than they should be, because there is some attraction between their molecules, and, when they expand, they perform internal work against this attractive force and consequently get colder. For air at 0 degrees C. this is worth 0.25 K for a pressure drop of 1 atmosphere and the effect gets greater at lower temperatures. Linde's first liquid air machine is shown on Fig. 4. Air was compressed to 65 atm., then throttled to 20 atm. On May 29, 1895, it achieved an output of 3 litres per hour at minus 165 degs C. On discharging the liquid air into a flask the temperature fell to minus 190 degs. C. and the liquid was found to be 70 per cent oxygen. Later machines were multi-stage, attaining a maximum pressure of 200 atm. when throttled to 40 or 50 atm.; by 1898 such a machine would produce 50 litres/hour.

Linde went on to develop methods of separating the nitrogen and oxygen. In 1909 he perfected a process for producing hydrogen from water gas by condensing the carbon monoxide. He founded a group of enterprises in Europe and America to exploit his inventions. He married in 1866 and had six children, and he died in Munich in his 93rd year.

Linde had begun his involvement with refrigeration at about the time that Harrison had retired, defeated but not downhearted. Harrison had been a battler, lacking capital or skilled assistants; his worst error had been to choose a dangerous and inconvenient refrigerant, probably because Lavoisier had used it years before to demonstrate cold production in the laboratory. For this reason Harrison's machines were regarded with suspicion and were soon superseded by cold air or absorption plant. Linde, described as a simple man of strong moral character, possessed the combination of scientific knowledge, engineering skill and business ability essential for success. He also had the good fortune to operate in a suitable environment, namely, the expanding economy of unified Germany, where capital and engineering assistance were readily available. Modern ammonia compressors and modern liquid air plant are directly descended from his early work. ■

7. Design and Operation of Linde Machines

The following extract from *The Mechanical Production of Cold* [Sir J A Ewing, 1923, Cambridge University Press, Cambridge, pp86-90] describes the design and operation of Linde's machines. The compressor cylinder shown in Figure 32 is the same as that used in the Urrbrae House machine.

Ammonia Machines (Linde).

The ammonia machine was introduced by Dr Carl Linde, then a professor at Munich, in the year 1876, and was brought into use in the following year. His English Patent was No. 1458 of 1876. The convenient range of pressure of ammonia and the comparatively small bulk of the machine commend it to general acceptance, and, further, it has, as I have pointed out, a thermodynamic advantage, in giving a cycle which makes a closer approach to the ideal cycle of Carnot than is got with any of the other substances that are practically used. The design of the Linde machine has been carried out with conspicuous care, and it owes much of its great success to excellence in mechanical detail.

A very large proportion of the whole work of refrigeration done for commercial purpose is now done by ammonia compression machines, especially in cases where economy of power is a leading consideration in determining the choice of apparatus. For there can be no question that, whatever the merits of other types, the ammonia compression machine stands easily first as regards the ratio of refrigerating effect to power expended in producing it.

Fig. 32 shows in section a compressor of the characteristic Linde type. It is double-acting, with spring inlet and delivery valves at each end. The valves in the ends of the cylinder are so arranged as to make the clearance space particularly small – something like half of one per cent. of the volume swept through by the piston. This secures a nearly complete delivery of the contents of the cylinder at each stroke. An interesting detail about these machines is the construction of the stuffing-box. To prevent escape of the ammonia the device is adopted which used to be called in steam-engines a lantern brass. The packing is divided into two parts, with a hollow space in the middle, and the space is in this example connected by a pipe with the suction side of the machine. Hence any ammonia which leaks through the inner part of the packing is carried away to the suction side, and not lost, and the outer part of the packing is exposed to no more [*page 86*] pressure than the difference between the pressure on the suction side and that of the atmosphere. Any leakage to the outside depends upon that difference of pressure, and not on the much larger difference of pressure which exists between the compression side of the machine and the atmosphere. Another point of importance is the lubrication. Oil circulates through a hollow in the gland, and spreads itself over the surface of the piston-rod. No more oil is used than is required for the lubrication of the piston-rod. In this respect the Linde machine differs from some other examples of ammonia machines, in which oil is injected into the cylinder and is allowed to mix in considerable quantity with the working vapour. [In the later practice of the Linde Company the use of a circulating pump for the oil is abandoned, it being found sufficient to use a sight-drop lubricator which allows a small quantity of oil to enter the cavity of the gland and so lubricate the rod.]

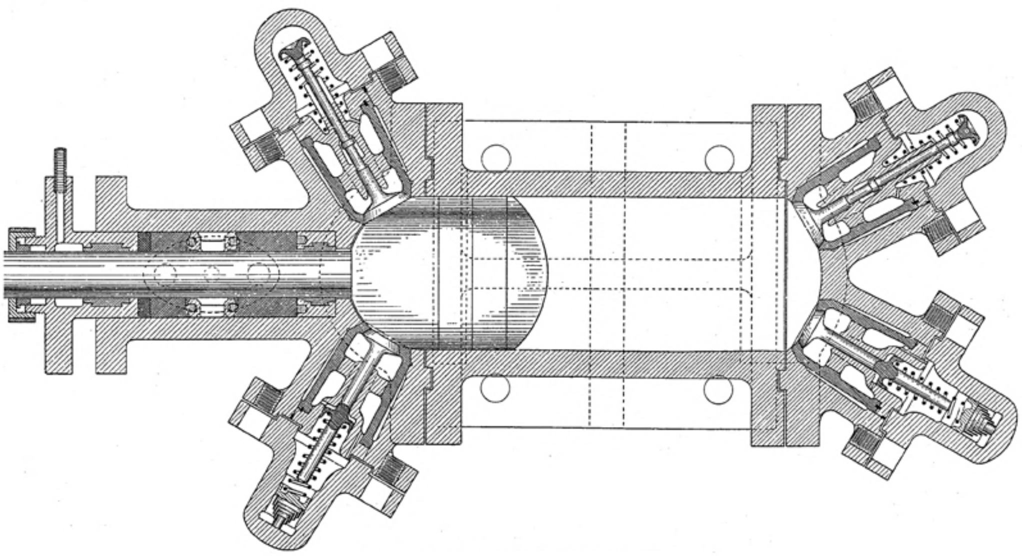


Fig. 32. Compressing Cylinder of the Linde Ammonia Machine.

Even here, however, there will be some slight admixture of oil with the ammonia, and as it is desirable to remove the oil before the ammonia is condensed, in order to prevent a deposit which would interfere with the activity of the condensing surfaces, an oil separator is used in the larger sizes of the Linde machine. This is an upright vessel, through which the ammonia from the compressor passes, depositing in the bottom any oil that it brings over. The oil is drained into a second vessel below, which is exposed to the suction pressure only, so that most of the ammonia contained in the oil evaporates before the oil is drawn off. The machine and all parts of the system are made of iron and steel, no brass or copper being permissible. There is no water jacket, for wet compression is used, and the ammonia when it leaves the cylinder is cool. Linde usually makes his compression cylinder horizontal, except in the smallest sizes; the steam cylinder is also horizontal, and drives on a crank set at right angles to the crank of the compressor. This form is preferred to the tandem arrangement of steam and compression cylinders, on the ground that it gives a more uniform crank-effort. With the tandem arrangement the steam-pressure is least when the compressor pressure is greatest.

[In the more recent practice of the German Linde Company the tendency is to use dry compression, and water jacketing is resorted to in the larger machines, but the British Linde Company continues to prefer wet compression, which is claimed to have the advantage that it enables the regulation to be more easily effected [*page 88*] which is required to maintain a maximum of efficiency in working, and that it keeps all parts of the compressor cool and so permits of good lubrication.]

In the largest sizes the machines have an ice-making capacity of about 60 tons of ice a day, for a single compressor, but two compressors are not unfrequently combined in one machine. As made for marine use, the compressor is occasionally compound, the process of compression being conducted in two successive stages. [*page 89*]

In another form of large machine, a compound horizontal steam-engine is used along with two parallel compressors, each steam cylinder being set tandem with one compressor cylinder. An example of the Linde machine, in one of its marine types, is shown in Fig. 33. In the hands of Dr Linde's companies in England, on the Continent of Europe, and in America, the ammonia compression machine has achieved a very conspicuous success. The result of tests will be quoted, in the next lecture, illustrating the performance of the ammonia compression machine. For use in cases where large amounts of refrigeration have to be effected, its high efficiency gives it preeminence over other types. For use in confined spaces on shipboard, however, ammonia is by no means an ideal working substance, and the question of efficiency gives place to other considerations which often lead to the selection of types in which the co-efficient of performance is less. [*page 90*]

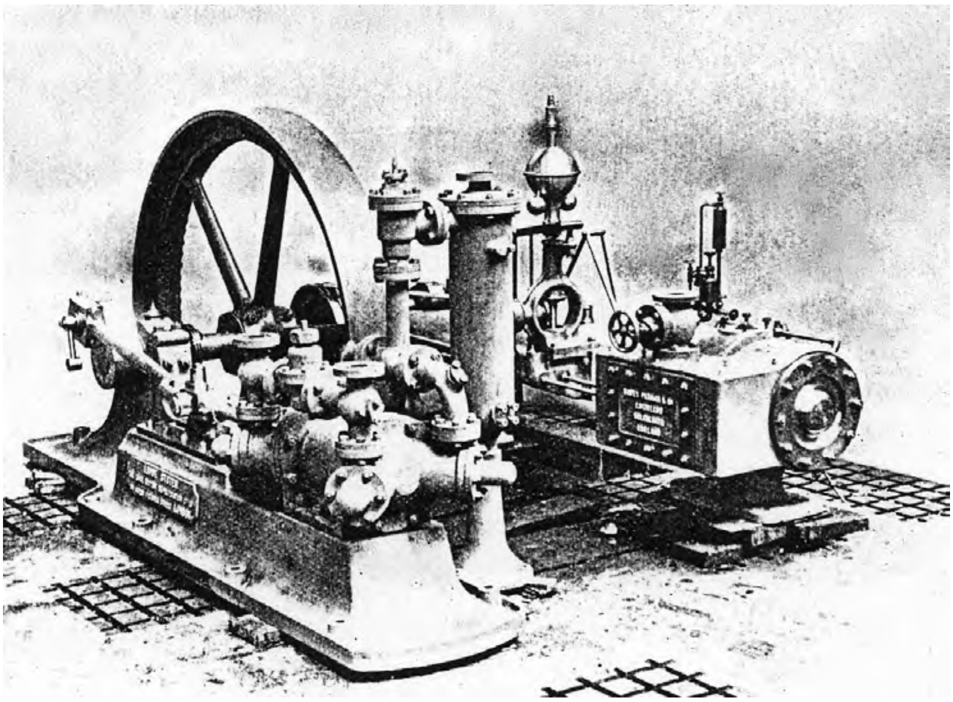


Fig. 33. Linde Ammonia Machine. Land type.

9. Significance of Linde's Design

This extract from A F Burstall's *A History of Mechanical Engineering* [1963, Faber, London, p352] confirms the importance of Linde's design in the development of ammonia refrigeration:

Most of the important events that have taken place in the history of refrigeration occurred in this period. We saw in the last chapter how Jacob Perkins invented the first vapour compression machine in 1834. In 1857 this type of machine was used by James Harrison of Geelong, Australia, to make possible the export of chilled meat through the tropics to England. This led to the rapid development of his process for which other working fluids such as ether, methyl chloride and sulphurous acid came to be used. Probably the most

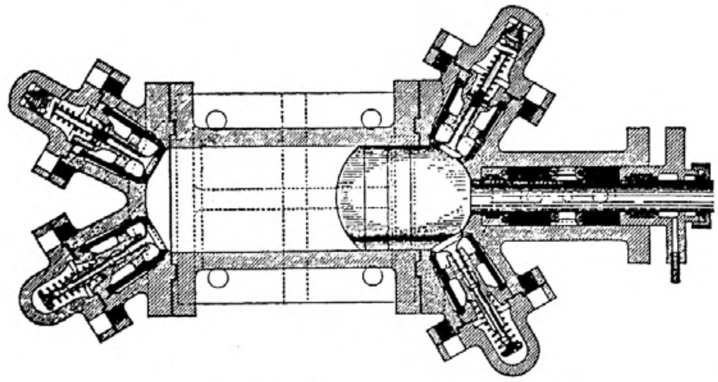


Fig. 242. Linde's ammonia compressor.

important step was that taken when Dr. Carl Linde introduced the ammonia machine in 1876 (Fig. 242). Ammonia has a considerable thermodynamic advantage over other fluids used, in that the cycle of operations can be made to approach more closely to the ideal Carnot cycle and for this reason it has remained popular for large-scale industrial refrigeration. It also had the advantage that for reaching normal freezing temperatures (not lower than −4° F.) from 86° F. the pressure of the cycle ranges between 20 lb./sq. in. and 170 lb./sq. in., which was similar to the pressures used in steam engine practice in those days. Another refrigerant which came into use in the 1880s was carbon dioxide. With this a pressure of over 1,000 lb./sq. in. occurs at the high pressure side, but the mechanical problems involved in using such high pressures (keeping joints and glands tight) were successfully overcome and such plants have continued to be favoured for marine work because they are more compact for a given output and any leakage is likely to be less dangerous.

9. The First Domestic Refrigeration Plant?

In June 1994, Professor Henry Cowan, emeritus Professor of Architecture at the University of Sydney, visited the refrigeration plant with Adelaide consulting engineer and member of the SA Heritage Branch committee, Hugh Orr Following that visit, a letter from Professor Cowan, to Deane Kemp, Heritage Branch Chairman, provided an informed opinion on the claim that the Urrbrae House plant was the first domestic refrigeration plant in Australia.

The Institution of Engineers, Australia
SOUTH AUSTRALIAN DIVISION

HGO/SH

24 June 1994

Dr Jennifer Gardiner
C/- Urrbrae House
The Waite Institute
Waite Road
URRBRAE SA 5064

Dear Jennifer

On behalf of the Heritage Branch Committee I would like to thank you very much for the hospitality you extended to Professor Cowan and me on Sunday 19 June 1994. It was very good of you to come in and open up the cool room for us and supply us with copies of papers and your background knowledge. The coffee was most welcome and kept us going to the rest of the afternoon.

Professor Cowan was most interested in the refrigeration equipment and the beautifully built coolroom - he told me the next day that the equipment may in fact be the oldest refrigeration equipment in existence in the world. If this is the case it would be another unique feature of Urrbrae House.

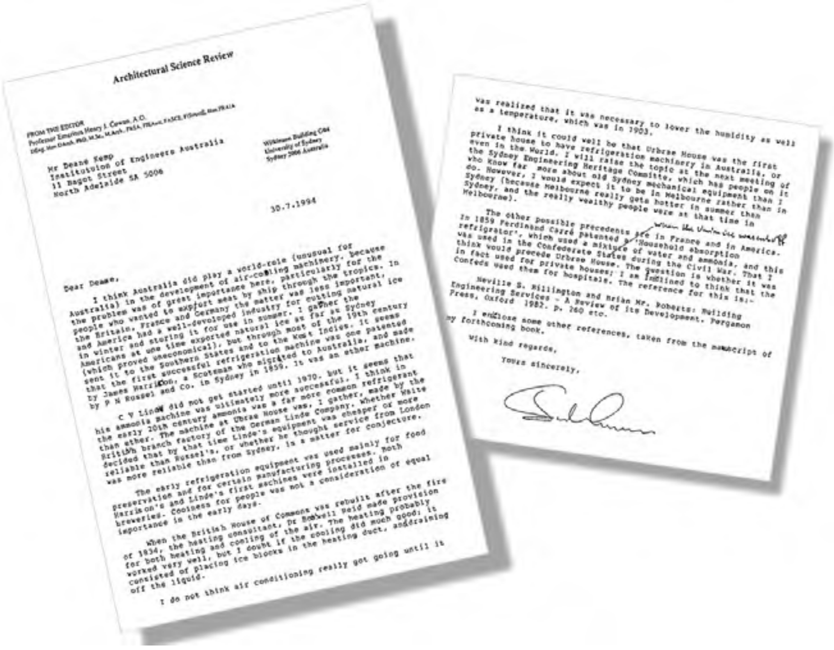
Thank you again.

Yours sincerely

Hugh

HG ORR, FIEAust, CP Eng

Engineering House, 11 Bagot Street, North Adelaide, S.A. 5006 Phone (08) 267 1783 Fax (08) 239 0932



Architectural Science Review

FROM THE EDITOR
Professor **Emeritus Henry J.** Cowan, A.O.
DEng. Hon.DArch, **PhD, M.Sc..** M.Arch.. FRSA, FIEAust, FASCE, FIStructE, Hon.FRAIA
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University of Sydney
Sydney 2006 Australia

30.7.1994

Mr Deane Kemp
Institution of Engineers Australia
ll Bagot Street
North Adelaide SA 5006

Dear Deane,
I think Australia did play a world-role (unusual for Australia) in the development of air-cooling machinery, because the problem was of great importance here, particularly for the people who wanted to export meat by ship through the tropics. In Britain, France and Germany the matter was less important, and America had a well-developed industry for cutting natural ice in winter and storing it for use in summer. I gather the Americans at one time exported natural ice as far as Sydney (which proved uneconomical), but through most of the 19th century sent it to the Southern States and to the West Indies. It seems that the first successful refrigeration machine was one patented by James Harrison, a Scotsman who migrated to Australia, and made by P N Russel and Co. in Sydney in 1859. It was an ether machine.

C V Linde did not get started until 1870, but it seems that his ammonia machine was ultimately more successful. I think in the early 20th century ammonia was a far more common refrigerant than ether. The machine at Urrbrae House was, I gather, made by the British branch factory of the German Linde Company. Whether Waite decided that by that time Linde’s equipment was cheaper or more reliable than Russell’s, or whether he thought service from London was more reliable than from Sydney, is a matter for conjecture.

The early refrigeration equipment was used mainly for food preservation and for certain manufacturing processes. Both Harrison’s and Linde’s first machines were installed in breweries. Coolness for people was not a consideration of equal importance in the early days.

When the British House of Commons was rebuilt after the fire of 1834, the heating consultant, Dr Boswell Reid made provision for both heating and cooling of the air. The heating probably worked very well, but I doubt if the cooling did much good; it consisted of placing ice blocks in the heating duct, and draining off the liquid.

I do not think air conditioning really got going until it was realized that it was necessary to lower the humidity as well as the temperature, which was in 1903.

I think it could well be that Urrbrae House was the first private house to have refrigeration machinery in Australia, or even in the World. I will raise the topic at the next meeting of the Sydney Engineering Heritage Committee which has people on it who know far more about old Sydney mechanical equipment than I do. However, I would expect it to be in Melbourne rather than in Sydney (because Melbourne really gets hotter in summer than Sydney, and the really wealthy people were at that time in Melbourne).

The other possible precedents are in France and in America. In 1859 Ferdinand Carré patented a 'Household absorption refrigerator', which used a mixture of water and ammonia, and this was used in the Confederate States when the Union ice was cut off during the Civil War. That I think would precede Urrbrae House. The question is whether it was in fact used for private houses; I am inclined to think that the Confeds used them for hospitals. The reference for this is: -
Neville S. Billington and Brian Mr. Roberts: Building Engineering Services - A Review of its Development. Pergamon Press, Oxford 1982. p. 260 etc.

I enclose some other references, taken from the manuscript of my forthcoming book.

With kind regards,
Yours sincerely,